Association between economic growth and early childhood undernutrition: evidence from 121 Demographic and Health Surveys from 36 low-income and middle-income countries

Sebastian Vollmer, Kenneth Harttgen, Malavika A Subramanyam, Jocelyn Finlay, Stephan Klasen, S V Subramanian

Summary

Background Economic growth is widely regarded as a necessary, and often sufficient, condition for the improvement of population health. We aimed to assess whether macroeconomic growth was associated with reductions in early childhood undernutrition in low-income and middle-income countries.

Methods We analysed data from 121 Demographic and Health Surveys from 36 countries done between Jan 1, 1990, and Dec 31, 2011. The sample consisted of nationally representative cross-sectional surveys of children aged 0–35 months, and the outcome variables were stunting, underweight, and wasting. The main independent variable was per-head gross domestic product (GDP) in constant prices and adjusted for purchasing power parity. We used logistic regression models to estimate the association between changes in per-head GDP and changes in child undernutrition outcomes. Models were adjusted for country fixed effects, survey-year fixed effects, clustering, and demographic and socioeconomic covariates for the child, mother, and household.

Findings Sample sizes were 462 854 for stunting, 485 152 for underweight, and 459 538 for wasting. Overall, 35·6% (95% CI 35·4–35·9) of young children were stunted (ranging from 8·7% [7·6–9·7] in Jordan to 51·1% [49·1–53·1] in Niger), 22·7% (22·5–22·9) were underweight (ranging from 1·8% [1·3–2·3] in Jordan to 41·7% [41·1–42·3] in India), and 12·8% (12·6–12·9) were wasted (ranging from 1·2% [0·6–1·8] in Peru to 28·8% [27·5–30·0] in Burkina Faso). At the country level, no association was seen between average changes in the prevalence of child undernutrition outcomes and average growth of per-head GDP. In models adjusted only for country and survey-year fixed effects, a 5% increase in per-head GDP was associated with an odds ratio (OR) of 0·993 (95% CI 0·989–0·995) for stunting, 0·986 (0·982–0·990) for underweight, and 0·984 (0·981–0·986) for wasting. ORs after adjustment for the full set of covariates were 0·996 (0·993–1·000) for stunting, 0·989 (0·985–0·992) for underweight, and 0·983 (0·979–0·986) for wasting. These findings were consistent across various subsamples and for alternative variable specifications. Notably, no association was seen between per-head GDP and undernutrition in young children from the poorest household wealth quintile. ORs for the poorest wealth quintile were 0·997 (0·990–1·004) for stunting, 0·999 (0·991–1·008) for underweight, and 0·991 (0·978–1·004) for wasting.

Interpretation A quantitatively very small to null association was seen between increases in per-head GDP and reductions in early childhood undernutrition, emphasising the need for direct health investments to improve the nutritional status of children in low-income and middle-income countries.

Funding None.

Lancet Glob Health 2014; 2: e225–34

See **Comment** page e185

Department of Economics and Courant Research Centre "Poverty, Equity and Growth in Developing Countries", University of Göttingen, Göttingen, Germany (Prof S Vollmer PhD, Prof S Klasen PhD); **NADEL, ETH Zurich, Zurich, Switzerland** (K Harttgen PhD); **Social Sciences, Indian Institute of Technology Gandhinagar, Ahmedabad, Gujarat, India** (M A Subramanyam DSc); **and Harvard Center for Population and Development Studies, Harvard School of Public Health, Cambridge, MA, USA** (S Vollmer, J Finlay PhD, Prof S V Subramanian PhD)

Correspondence to:
Prof S V Subramanian, Harvard Center for Population and Development Studies, Cambridge, MA 02138, USA
svsubram@hsph.harvard.edu

or

Prof Sebastian Vollmer, Department of Economics, University of Göttingen, 37073 Göttingen, Germany
svollmer@uni-goettingen.de

Introduction

Increasing economic growth, as measured through increases in per-head gross domestic product (GDP), is the cornerstone of development policy for most national governments.[1] In countries with low per-head GDP, increasing the rate of economic growth is often justified as a key policy instrument for improving population health and nutrition.[2–4] The rationale is that increases in economic growth will lead to increases in average income, especially improving the incomes of poor people, which in turn will improve access to, and consumption of, goods and services that improve nutritional status and health.[5] Although such a growth-mediated strategy for improving population health and nutrition[6] is plausible, the empirical evidence to support this strategy remains unclear. Smith and Haddad[4] used aggregated data from 63 low-income and middle-income countries with measurements from 1970 to 1996 and reported a strong inverse association between national economic growth and childhood underweight. Headey[7] estimated the effect of economic growth on changes in undernutrition and showed that economic growth leads to a small but significant reduction in stunting. Such ecological analyses assume that the risk of undernutrition is the same for every child within a country, which, if invalid, can lead to a biased estimation of the association. Moreover, ecological analyses limit the scope for analysis of more detailed subnational drivers of undernutrition and within-country heterogeneity.

We identified only two studies that have examined the multilevel association of changes in aggregate macroeconomic growth with changes in the risk of an individual child being undernourished. Subramanyam and colleagues[8] reported that there was no consistent evidence that economic growth in various Indian states was associated with a reduction in childhood stunting, underweight, or wasting. Thus, at least for India, which accounts for the largest national share of the global burden of undernutrition,[9] the substantial increases in economic growth that the country experienced over the past two decades did not translate into a similarly substantial reduction in childhood undernutrition.[10] Harttgen and colleagues[11] examined the effect of economic growth on child undernutrition in sub-Saharan Africa using Demographic and Health Surveys (DHS) from the 1990s and 2000s and reported that growth had a small, inverse association with childhood stunting, underweight, and wasting.

Using the largest available, nationally representative, and mutually comparable repeated cross-sectional samples from 121 surveys in 36 low-income to middle-income countries, with objective measurements of childhood anthropometry, we investigated whether changes in national economic growth were associated with reductions in the prevalence of early childhood stunting, underweight, and wasting.

Methods

Data sources and procedures

Data were from the DHS, which are nationally representative cross-sectional surveys that have been done by ICF International in more than 82 low-income and middle-income countries at varying intervals since 1985. These surveys are designed to collect nationally representative health and welfare data for women of reproductive age, their children, and their households. We included surveys done between Jan 1, 1990, and Dec 31, 2011, in the analysis.

The DHS used a multistage stratified sampling design. In the first stage of sampling, each country was divided into regions, which are either political regions such as states or provinces, or geographical areas divided and labelled north, south, east, and west. Within these subnational regions, populations were stratified by urban and rural area of residence. Within these stratified areas, a random selection of enumeration areas taken from the most recent population census was drawn. These primary sampling units (clusters) were selected such that the probability of each cluster being selected was equal to the proportion that specific cluster's population contributed to the total population. In the second stage of sampling, all households within the cluster were listed and an average of 25 houses within a cluster were randomly selected for an interview by equal-probability systematic sampling. Detailed sampling plans are available from the final survey reports.[12]

For each sampled household, members were listed and women eligible for a child health interview were identified. The women interviewed were typically between the ages of 15 and 49 years, although in some surveys the age range was 10–49 years, and a few were restricted to married and previously married women. Heights and weights of children born in the past 3 or 5 years at the time of interview were also recorded. For consistency across all surveys, only data from children

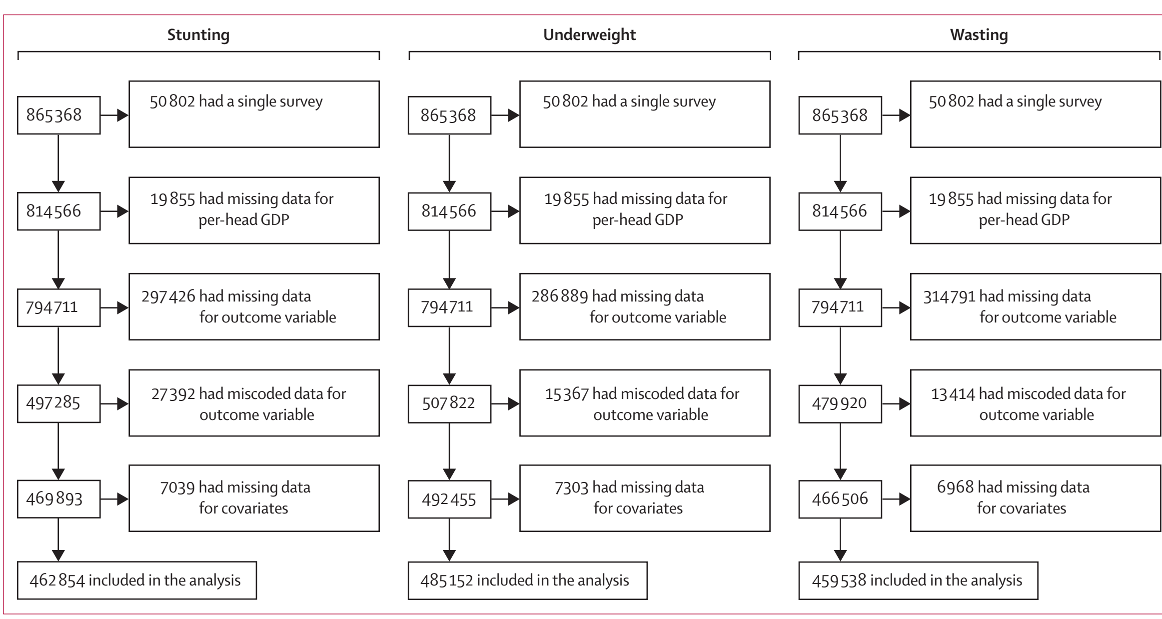

Figure 1: **Sample selection**
GDP=gross domestic product.

aged 0–35 months were included in the analysis. The DHS provided sampling weights for the calculation of nationally representative statistics.

We used national aggregate data for per-head GDP from the Penn World Tables 8.0.[13] These tables provide data for real per-head GDP, adjusted for purchasing power parity exchange rates and reported in 2005 International Comparison Program prices (in international dollars). The adjustment for purchasing power parity between countries makes the level and growth of per-head GDP comparable between countries and over time. We used per-head GDP measured in natural logarithmic units to model a potentially non-linear association with early childhood undernutrition. We merged the individual data from the DHS with the data for per-head GDP by country and year. Children in the same survey (ie, same country and year) were assigned the same per-head GDP, which is representative of the national average.

The DHS data-collection procedures were approved by the ICF International (Calverton, MD, USA) institutional

	Survey year	Stunting sample		Underweight sample		Wasting sample		GDP per head*	Economic growth†
		N	Proportion stunted (95% CI)	N	Proportion underweight (95% CI)	N	Proportion wasted (95% CI)		
Armenia	2010	860	19·4% (16·7–22·0)	875	5·4% (3·9–6·9)	850	4·1% (2·8–5·4)	$5002	2·8%
Bangladesh	2007	3238	40·3% (38·6–42·0)	3313	38·9% (37·2–40·6)	3218	19·4% (18·0–20·7)	$1314	3·7%
Benin	2006	7956	42·2% (41·1–43·3)	8412	19·4% (18·6–20·3)	8105	10·2% (9·5–10·9)	$1226	0·9%
Bolivia	2008	4709	25·5% (24·2–26·7)	4754	5·6% (5·0–6·3)	4675	2·2% (1·8–2·7)	$3795	4·7%
Burkina Faso	2003	5172	38·6% (37·3–40·0)	5360	37·6% (36·3–38·9)	5012	28·8% (27·5–30·0)	$799	2·2%
Cameroon	2011	3309	29·8% (28·3–31·4)	3368	14·8% (13·6–16·0)	3310	7·8% (6·9–8·7)	$1858	0·7%
Chad	2004	2705	38·9% (37·0–40·7)	2784	33·3% (31·6–35·1)	2671	21·0% (19·5–22·6)	$1471	7·6%
Colombia	2009	9469	13·3% (12·6–14·0)	9486	3·7% (3·3–4·1)	9453	1·2% (0·9–1·4)	$7481	3·9%
Côte d'Ivoire	1998	1034	27·8% (25·1–30·5)	1054	17·4% (15·1–19·7)	1026	9·0% (7·3–10·8)	$2069	1·1%
Dominican Republic	2007	5554	10·9% (10·1–11·8)	5623	3·6% (3·2–4·1)	5521	2·6% (2·2–3·0)	$7671	3·8%
Egypt	2008	6247	31·0% (29·8–32·1)	6602	6·7% (6·1–7·4)	6178	9·0% (8·3–9·7)	$4513	4·3%
Ethiopia	2011	5663	38·3% (37·0–39·6)	5824	26·9% (25·7–28·0)	5646	13·3% (12·4–14·1)	$783	8·1%
Ghana	2008	1504	25·0% (22·8–27·2)	1593	14·9% (13·2–16·7)	1497	12·6% (10·9–14·3)	$1988	3·6%
Guinea	2005	1692	36·1% (33·8–38·3)	1730	23·2% (21·2–25·2)	1688	14·4% (12·7–16·1)	$909	–7·1%
India	2005	24 924	45·1% (44·5–45·7)	25 909	41·7% (41·1–42·3)	24 586	23·4% (22·9–24·0)	$2415	5·2%
Jordan	2009	2736	8·7% (7·6–9·7)	2760	1·8% (1·3–2·3)	2731	1·9% (1·4–2·4)	$5102	6·2%
Kazakhstan	1999	328	13·7% (9·9–17·4)	331	4·0% (1·9–6·1)	324	3·3% (1·3–5·2)	$4710	–3·0%
Kenya	2009	3215	36·7% (35·0–38·4)	3346	14·9% (13·7–16·1)	3204	7·8% (6·9–8·7)	$1232	1·0%
Lesotho	2009	1050	33·1% (30·2–35·9)	1069	13·3% (11·3–15·3)	1052	5·1% (3·8–6·4)	$1315	3·7%
Madagascar	2004	2776	50·2% (48·3–52·0)	2875	34·5% (32·7–36·2)	2773	17·9% (16·5–19·3)	$767	–0·8%
Malawi	2010	2892	46·8% (45·0–48·7)	3038	13·9% (12·7–15·1)	2855	5·4% (4·6–6·3)	$795	6·5%
Mali	2006	7124	36·1% (35·0–37·2)	7289	28·7% (27·7–29·8)	6998	19·9% (19·0–20·9)	$876	0·3%
Morocco	2003	3111	25·0% (23·5–26·5)	3192	8·6% (7·6–9·5)	3065	10·7% (9·6–11·7)	$3226	–1·2%
Mozambique	2003	5005	43·9% (42·5–45·3)	5104	23·2% (22·1–24·4)	5017	7·1% (6·4–7·8)	$523	5·1%
Namibia	2007	2440	29·5% (27·7–31·4)	2487	16·2% (14·7–17·6)	2421	8·2% (7·1–9·3)	$4941	4·0%
Nepal	2011	520	50·2% (45·9–54·5)	522	38·2% (34·0–42·4)	517	16·9% (13·7–20·1)	$1185	3·7%
Niger	2006	2361	51·1% (49·1–53·1)	2436	38·6% (36·6–40·5)	2362	16·5% (15·0–18·0)	$535	–0·9%
Nigeria	2008	12 490	40·4% (39·6–41·3)	14 165	27·0% (26·2–27·7)	12 239	16·5% (15·8–17·1)	$1896	18·7%
Peru	2004	1264	26·2% (23·8–28·7)	1290	5·4% (4·1–6·6)	1258	1·2% (0·6–1·8)	$5266	4·1%
Rwanda	2010	2427	41·0% (39·0–42·9)	2440	11·9% (10·6–13·2)	2419	4·0% (3·2–4·8)	$1135	5·3%
Senegal	2011	2379	28·1% (26·3–29·9)	2448	17·3% (15·8–18·8)	2380	10·0% (8·8–11·2)	$1412	–0·4%
Tanzania	2004	4665	40·9% (39·4–42·3)	4720	16·0% (15·0–17·1)	4656	4·6% (4·0–5·2)	$891	4·0%
Turkey	2003	2308	13·4% (12·0–14·7)	2368	2·7% (2·1–3·4)	2294	1·5% (1·0–2·0)	$9173	–1·9%
Uganda	2011	1319	31·4% (28·9–33·9)	1342	15·2% (13·2–17·1)	1315	6·8% (5·5–8·2)	$1187	3·0%
Zambia	2007	3308	43·8% (42·1–45·5)	3492	14·9% (13·7–16·0)	3310	7·3% (6·4–8·2)	$1685	7·2%
Zimbabwe	2011	2924	32·1% (30·4–33·8)	2990	10·3% (9·2–11·4)	2908	4·3% (3·6–5·1)	$4348	6·6%

Data are from the most recent Demographic and Health Survey (DHS) for each country included in the analysis. N is the sample size. GDP=gross domestic product. *International dollars in constant prices (adjusted for purchasing power parity and inflation). †Average annual growth rate of GDP per head between DHS surveys.

Table 1: **Prevalence of child undernutrition, by country**

review board and by the relevant human subjects committees in each country. Survey respondents provided oral informed consent. This study was assessed by the Harvard School of Public Health (Boston, MA, USA) institutional review board and ruled exempt from full review because it was based on an anonymised public-use dataset.

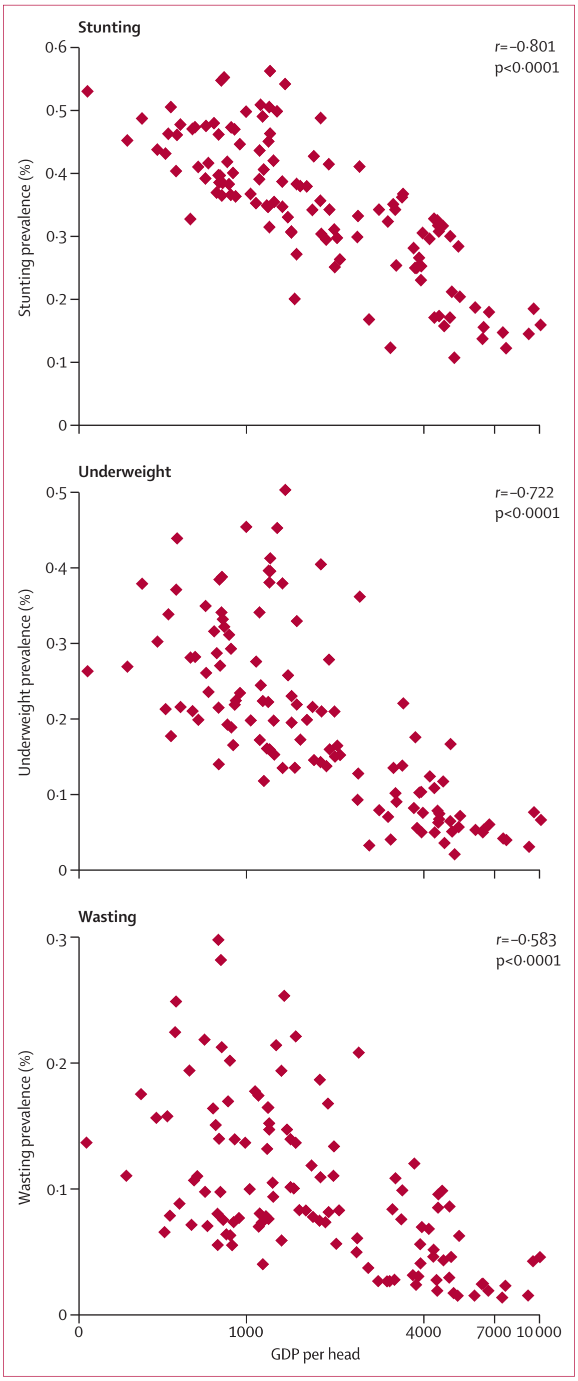

Figure 2: **Correlation between prevalence of early childhood undernutrition outcomes and log of per-head GDP**
n=121 surveys. GDP=gross domestic product.

Outcomes

We analysed the DHS data for three outcomes: stunting, underweight, and wasting in children aged 0–35 months at the time of interview. We used anthropometric data to calculate whether a child was stunted, underweight, or wasted as defined by WHO standards and classifications.[14] For stunting, we calculated a Z score as the child's height

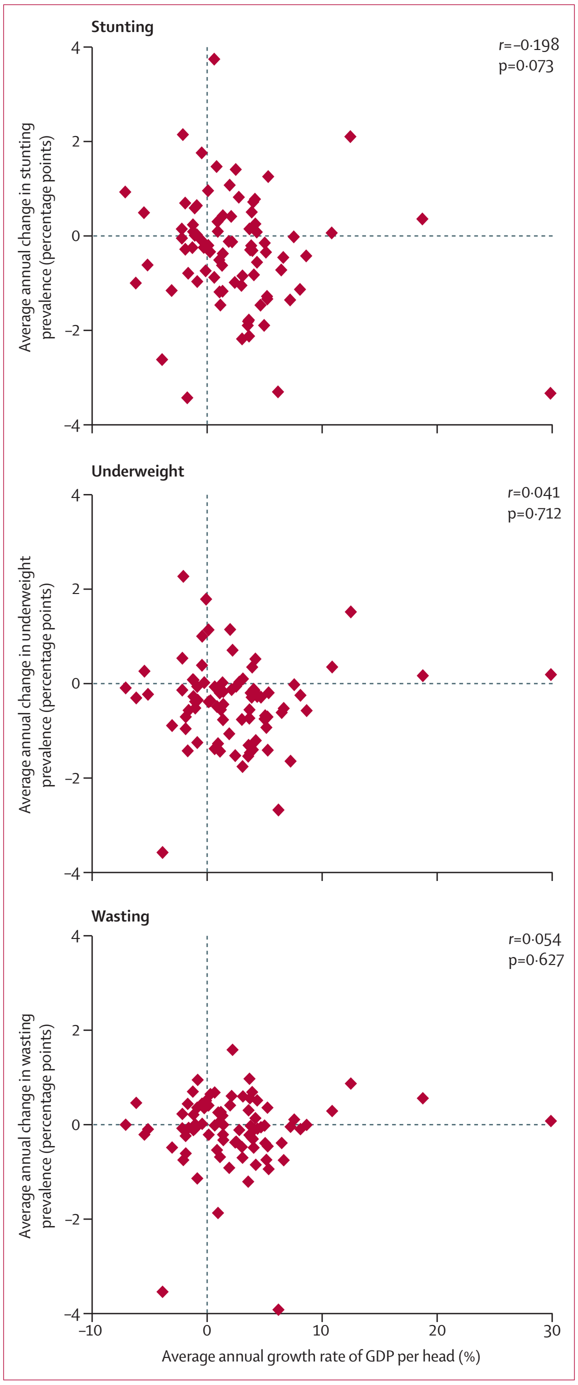

Figure 3: **Correlation between the change in prevalence of early childhood undernutrition outcomes and growth of per-head GDP**
n=85 surveys (121 minus 36). GDP=gross domestic product.

minus the median height for that child's age and sex in the WHO reference population,[15] divided by the standard deviation of this group in the reference population.[15] We did similar calculations to establish *Z* scores for weight (for underweight) and weight-for-height (for wasting, an indicator of acute undernutrition). Stunting, underweight, and wasting were defined by *Z* scores of less than –2; *Z* scores of less than –3 were classified as severe. Biologically implausible values (defined by WHO for height as a *Z* score of less than –6 or greater than 6, for weight as a *Z* score of less than –6 or greater than 5, and for weight for height as a *Z* score of less than –5 or greater than 5)[14] were excluded.

We used age, sex, and birth order of the child; the mother's age at birth, education, and relationship status; household wealth quintile; and urban or rural residence as covariates for the analysis. Wealth quintile is a within-country measure of the wealth of the household relative to other households in that survey, based on ownership of household assets.[16] Although several of these factors could be mediators of the association between economic growth and early childhood undernutrition, they are also modifiable by direct investment in social programmes. We therefore examined the association with and without adjustment for these factors.

Statistical analysis

We specified a series of logistic regression models for stunting, underweight, and wasting as outcome variables. For each outcome, we adjusted the models for country and survey-year fixed effects. We clustered standard errors by country and by primary sampling unit. We also specified regression models for various subsamples and alternative variable specifications: the poorest and richest wealth quintiles; children aged 0–11, 12–23, and 24–35 months; sub-Saharan African countries, Asian countries, and Latin American countries; low-income, lower-middle-income, and upper-middle-income countries; severe stunting, severe underweight, and severe wasting as outcome variables; log of per-head GDP from the previous year instead of the concurrent year as an alternative independent variable. We excluded Egypt and Turkey from the regional analysis since they do not fit clearly into the regional categories. To allow interpretation, we report the odds ratios (ORs) for a 5% increase in per-head GDP. For all analyses, associations with a p value of less than 0·05 were regarded as significant. All statistical analyses were done with Stata 13.

We also did several sensitivity analyses based on a linear probability model. First, we reweighted the observations with the population size of the country. Second, we trimmed the sample to exclude extreme observations that might have an especially large effect on the results. Third, we used instrumental variable regressions with the investment share of GDP 5 years previous to any given year used in the analysis as an instrument for log of the per-head GDP[3,17] to address two potential statistical problems: measurement error, particularly in GDP, which could bias the results downwards; and the endogenous nature of GDP, which could bias the findings because of either reverse causality or the effect of unmeasured variables on the association between per-head GDP and undernutrition.

Role of the funding source

There was no funding source for this study.

Results

172 surveys done between Jan 1, 1990, and Dec 31, 2011, in 64 countries had recorded anthropometric data for 865 368 children born up to 3 years before the time of interview. Because our aim was to examine the effect of economic growth over time, we excluded children from countries for which data from only one survey were available. Other exclusions resulted from missing data for GDP, outcome variables, and covariates, resulting in a sample of 462 854 for the stunting analysis, 485 152 for the underweight analysis, and 459 538 for the wasting analysis (figure 1). These samples include data from 121 surveys in 36 countries.

Of the 36 countries included in the study, 34 had their most recent survey between 2003 and 2011 (table 1). The most recent survey for India was done in 2005, which with data for 24 924 children in the stunting analysis was the largest of the most recent surveys included. Across all of the most recent surveys included in the study, those for Kazakhstan (n=328) and Nepal (n=520) were by far the smallest. Six surveys had a sample size between 1000 and 1999; 17 surveys between 2000 and 4999; and eight between 5000 and 9999 (table 1).

Overall, 35·6% (95% CI 35·4–35·9) of young children were stunted, 22·7% (22·5–22·9) were underweight, and 12·8% (12·6–12·9) were wasted. Jordan had the lowest prevalence of stunting and underweight, and Peru the lowest prevalence for wasting. Niger had the highest prevalence of stunting, India of underweight, and Burkina Faso of wasting (table 1).

The average annual growth of per-head GDP between survey years varied substantially between countries (table 1). Nigeria had the strongest average growth rate of per-head GDP at 18·7% per year between the two most recent surveys in 2003 and 2008. Seven countries showed negative growth between survey years, but 16 had growth rates between 1% and 5% (table 1).

Using the most recent surveys from each country, we calculated the average child undernutrition outcomes by categorical covariates (appendix pp 1–2). Over time, the prevalence of stunting, underweight, and wasting changed within countries, as did the per-head GDP and its associated growth rate. For most countries, the prevalence of early childhood undernutrition fell and per-head income increased (appendix pp 3–5). Across countries and time, if a child was stunted, that child lived in an

See Online for appendix

	Adjusted			Unadjusted		
	Stunted	Wasted	Underweight	Stunted	Wasted	Underweight
Full sample						
OR (95% CI)	0·996 (0·993–1·000)	0·983 (0·979–0·986)	0·989 (0·985–0·992)	0·993 (0·989–0·995)	0·984 (0·981–0·986)	0·986 (0·982–0·990)
p value	0·021	<0·0001	<0·0001	<0·0001	<0·0001	<0·0001
N	462 854	459 538	485 152	462 854	459 538	485 152
Poorest wealth quintile						
OR (95% CI)	0·997 (0·990–1·004)	0·991 (0·978–1·004)	0·999 (0·991–1·008)	0·995 (0·992–0·998)	0·985 (0·982–0·987)	0·988 (0·983–0·993)
p value	0·367	0·153	0·784	0·002	<0·0001	<0·0001
N	104 040	103 473	109 329	104 040	103 473	109 329
Richest wealth quintile						
OR (95% CI)	0·997 (0·992–1·001)	0·984 (0·981–0·987)	0·990 (0·987–0·993)	0·990 (0·987–0·993)	0·983 (0·981–0·986)	0·985 (0·980–0·989)
p value	0·086	<0·0001	<0·0001	<0·0001	<0·0001	<0·0001
N	74 575	73 902	77 883	74 575	73 907	77 888
Children aged 0–11 months						
OR (95% CI)	0·991 (0·981–1·001)	0·998 (0·988–1·008)	0·994 (0·987–1·001)	0·989 (0·985–0·993)	0·985 (0·982–0·989)	0·987 (0·984–0·989)
p value	0·071	0·593	0·054	<0·0001	<0·0001	<0·0001
N	162 048	158 770	170 633	162 048	158 770	170 633
Children aged 12–23 months						
OR (95% CI)	0·989 (0·979–1·000)	0·989 (0·977–1·002)	0·996 (0·985–1·006)	0·993 (0·990–0·997)	0·983 (0·981–0·986)	0·985 (0·979–0·991)
p value	0·035	0·085	0·372	0·0002	<0·0001	<0·0001
N	155 071	155 437	162 378	155 071	155 437	162 378
Children 24–35 months						
OR (95% CI)	0·997 (0·994–1·000)	0·982 (0·979–0·986)	0·988 (0·984–0·992)	0·995 (0·993–0·997)	0·982 (0·979–0·985)	0·986 (0·982–0·990)
p value	0·008	<0·0001	<0·0001	<0·0001	<0·0001	<0·0001
N	145 734	145 330	152 140	145 735	145 331	152 141
Sub-Saharan Africa						
OR (95% CI)	0·996 (0·994–0·997)	0·984 (0·981–0·986)	0·992 (0·990–0·994)	0·995 (0·994–0·996)	0·988 (0·986–0·991)	0·993 (0·992–0·995)
p value	<0·0001	<0·0001	<0·0001	<0·0001	<0·0001	<0·0001
N	241 448	239 546	250 507	241 448	239 547	250 508
Asia						
OR (95% CI)	0·999 (0·999–1·000)	0·979 (0·978–0·979)	0·984 (0·984–0·985)	0·992 (0·992–0·992)	0·978 (0·978–0·978)	0·980 (0·980–0·980)
p value	0·0002	<0·0001	<0·0001	<0·0001	<0·0001	<0·0001
N	112 342	111 587	123 619	112 342	111 587	123 619

(Table 2 continues on next page)

environment with an average per-head GDP of $2055, compared with $2896 for a child without stunting. A similar pattern was seen for underweight and wasting. As expected, an inverse cross-sectional ecological association was seen between the average child undernutrition outcomes and the per-head GDP of the country (figure 2); however, no association was seen between average changes in the prevalence of child undernutrition outcomes and average growth of per-head GDP (figure 3).

Table 2 shows the adjusted and unadjusted ORs for the full sample, subsamples, and alternative variable specifications. In models adjusted only for country and survey-year fixed effects, a 5% increase in per-head GDP was associated with a 0·7% decrease in the odds of being stunted (p<0·0001), a 1·4% decrease in the odds of being underweight (p<0·0001), and a 1·6% decrease in the odds of being wasted (p<0·0001). The respective figures from models adjusted for a full set of covariates were 0·4% for the odds of being stunted (p=0·021), 1·1% for the odds of being underweight (p<0·0001), and 1·7% for the odds of being wasted (p<0·0001). Results for all covariates are reported in the appendix (p 6).

For the various subsamples and alternative variable specifications, we noted several findings. First, the

	Adjusted			Unadjusted		
	Stunted	Wasted	Underweight	Stunted	Wasted	Underweight
(Continued from previous page)						
Latin America						
OR (95% CI)	0·996 (0·994–0·997)	0·977 (0·975–0·979)	0·985 (0·982–0·987)	0·994 (0·994–0·994)	0·979 (0·979–0·979)	0·984 (0·984–0·984)
p value	<0·0001	<0·0001	<0·0001	<0·0001	<0·0001	<0·0001
N	66 710	66 321	67 504	66 710	66 362	67 504
Low-income countries						
OR (95% CI)	1·003 (1·001–1·004)	0·998 (0·996–1·000)	0·985 (0·982–0·989)	1·000 (0·999–1·002)	0·999 (0·998–1·000)	0·989 (0·986–0·992)
p value	<0·0001	0·091	<0·0001	0·439	0·007	<0·0001
N	183 313	189 490	182 084	183 313	189 490	182 084
Lower-middle-income countries						
OR (95% CI)	0·994 (0·991–0·997)	0·990 (0·985–0·995)	0·981 (0·978–0·984)	0·990 (0·989–0·992)	0·987 (0·981–0·992)	0·982 (0·979–0·984)
p value	<0·0001	<0·0001	<0·0001	<0·0001	<0·0001	<0·0001
N	193 055	207 861	191 537	193 055	207 861	191 537
Upper-middle-income countries						
OR (95% CI)	0·997 (0·996–0·998)	0·985 (0·982–0·987)	0·975 (0·972–0·978)	0·995 (0·994–0·995)	0·984 (0·983–0·986)	0·976 (0·974–0·979)
p value	<0·0001	<0·0001	<0·0001	<0·0001	<0·0001	<0·0001
N	86 486	87 801	85 876	86 486	87 801	85 876
Severe undernutrition as outcome variables						
OR (95% CI)	0·988 (0·984–0·991)	0·977 (0·972–0·981)	0·985 (0·979–0·991)	0·985 (0·982–0·988)	0·978 (0·974–0·982)	0·981 (0·975–0·988)
p value	<0·0001	<0·0001	<0·0001	<0·0001	<0·0001	<0·0001
N	462 854	459538	485 152	462 854	459 538	485 152
Log of per-head GDP from the previous year as an independent variabl						
OR (95% CI)	0·996 (0·993–1·000)	0·983 (0·980–0·986)	0·989 (0·986–0·993)	0·993 (0·990–0·995)	0·984 (0·981–0·987)	0·987 (0·983–0·990)
p value	0·017	<0·0001	<0·0001	<0·0001	<0·0001	<0·0001
N	462 854	459 538	485 152	462 854	459 538	485 152

Data for per-head gross domestic product (GDP) were merged with Demographic and Health Survey data by survey year. SEs are clustered at the country level. Odds ratios (ORs) for the log of per-head GDP represent the difference in odds associated with a 5% increase in per-head GDP. All specifications include country and survey-year fixed effects. All ORs are rounded to three decimal places; thus an OR of 1·000 in the CI does not necessarily imply that the value 1 is included in the CI.

***Table 2:* Adjusted and unadjusted ORs for childhood undernutrition associated with the log of per-head GDP for various subsamples and alternative variable specifications**

associations between the log of per-head GDP and stunting, underweight, and wasting were null for the poorest wealth quintile. For the richest wealth quintile, the associations were similar to those for the full sample (table 2). Second, for children aged 0–11 months, the associations between per-head GDP and the three outcome variables were not significant. For children aged 12–23 months, a 5% increase in per-head GDP was associated with reduced odds of being stunted, but the associations between per-head GDP and underweight and wasting were not significant. For children aged 24–35 months, a 5% increase in per-head GDP was associated with slightly reduced odds of stunting, underweight, and wasting. Third, the finding of a quantitatively very small association between the log of per-head GDP and stunting, underweight, and wasting holds for countries subdivided by region into sub-Saharan Africa, Asia, and Latin America, as well as across World Bank classifications of low-income, lower-middle-income, and upper-middle-income countries. Fourth, a 5% increase in per-head GDP was associated with reduced odds of severe stunting, underweight, and wasting. Finally, the results were robust to the inclusion of the log of per-head GDP from the previous year instead of the concurrent year (table 2).

Table 3 shows the results from linear probability models and several sensitivity analyses fully adjusted for covariates, country fixed effects, and survey-year fixed effects. A 5% increase in per-head GDP was associated with a 0·3% reduced probability of stunting, a 0·2% reduced probability of underweight, and a 0·1% reduced probability of wasting. When we weighted the results by country population size, the probability decreased by 0·4% for stunting, 0·1% for underweight, and 0·1% for

	Stunting				Wasting				Underweight			
	Un-weighted model	Weighted by population size	Excluding first, second, third, 98th, 99th, and 100th percentiles	Instru-mental variable regression	Un-weighted model	Weighted by population size	Excluding first, second, third, 98th, 99th, and 100th percentiles	Instru-mental variable regression	Un-weighted model	Weighted by population size	Excluding first, second, third, 98th, 99th, and 100th percentiles	Instru-mental variable regression
Log of per-head GDP (SE)	–0·0025 (0·0008)	–0·0041 (0·0007)	–0·0022 (0·0008)	–0·0507 (0·1582)	–0·0008 (0·0004)	–0·0013 (0·0003)	–0·0008 (0·0004)	–0·0218 (0·0628)	–0·0017 (0·0007)	–0·0013 (0·0006)	–0·0017 (0·0006)	–0·0511 (0·1935)
p value	0·004	<0·0001	0·011	0·761	0·075	<0·0001	0·008	0·741	0·023	0·030	0·006	0·805
Number of observations	462 854	462 854	435 398	462 117	459 538	459 538	432 087	458 803	485 152	485 152	457 055	484 403

Data for per-head gross domestic product (GDP) were merged with Demographic and Health Survey data by survey year. All regressions are ordinary least squares and the instrumental variable regressions are two-stage least squares. All regression shown are adjusted for all covariates and for country and survey-year fixed effects. SEs are clustered at the country level. Coefficients for the log of per-head GDP represent a 5% increase in per-head GDP. In the instrumental variable regressions, we used the variable share of gross capital formation at present purchasing power parity (investment share of GDP) from the Penn World Tables 8.0,[13] with a 5-year lag as an instrument for the log of the per-head GDP.

Table 3: **Estimates from linear probability models, models weighted for population size, models after trimming extreme observations, and instrumental variable regression**

Panel: Research in context

Systematic review

We first searched Google Scholar for articles published in English from Jan 1, 1990, to Oct 25, 2013, that included the search terms "undernutrition" and "income" and "growth"; "malnutrition" and "income" and "growth"; "undernutrition" and "economic" and "growth"; or "malnutrition" and "economic" and "growth" in the title. These four searches identified 29 unique entries. We searched PubMed using the same search strategy and did not identify any additional reports. We selected only empirical studies that were published in peer-reviewed journals and were not mainly focused on the assessment of specific programme interventions for our discussion of the scientific literature. Only three of the reports[4,8,11] identified from these searches were relevant, along with one additional report[7] that was brought to our attention by a reviewer. Two studies[4,7] used country-level data and showed an inverse association between economic growth and child undernutrition. A multilevel study[8] that assessed state-level economic growth in India showed no consistent evidence for an association between economic growth and child undernutrition. Another multilevel study,[11] which assessed country-level growth from the African continent, showed a small inverse association between economic growth and child undernutrition.

Interpretation

Our study is the first multilevel study to report estimates for the association between economic growth and early childhood stunting, underweight, and wasting for all low-income and middle-income countries for which nationally representative data are available and comparable across countries and over time. Our finding of a quantitatively very small to null association challenges the assumption that economic growth will automatically lead to reductions in child undernutrition.

wasting. When we excluded the first, second, third, 98th, 99th, and 100th percentiles of the outcome variables to examine whether and to what extent the results were biased by extreme observations, our main results were unaffected. In an instrumental variable regression that used the investment share of GDP from 5 years years previous to any given year used in the analysis as an instrument for log of the per-head GDP, the associations between the log of the per-head GDP and stunting, wasting, and underweight were not significant.

Discussion

Using data for child anthropometry from 121 surveys in 36 low-income and middle-income countries, we have shown that macroeconomic growth has a null to quantitatively very weak association with reductions in early childhood stunting, underweight, and wasting. This finding is robust for a wide variety of covariate adjustments, modelling approaches, and subsample analyses (panel).

Several plausible explanations could account for this result. First, the growth in incomes could be unequally distributed—if poor people are excluded from the benefits of growth, the effect of increased prosperity on average could be low. Second, even if rising incomes reach most households, they might not necessarily be spent in ways that enhance the nutritional status of children. A positive association would depend on how resources are allocated between food and non-food items, the quality of food purchased, and the distribution of food within households.[18–20] Third, rising average incomes could be poorly associated with improvements to public services that are essential to improve the nutritional status of the population (eg, vaccinations against diseases that can precipitate and maintain undernutrition, prenatal and postnatal care, clean water and sanitation, etc). As Drèze and Sen[6] have argued, progress in undernutrition can be achieved in low-income settings through investments in these public services, as places such as Sri Lanka, Kerala (India), and Costa Rica have shown. Conversely, high-income growth does not guarantee the provision of these services, which are typically provided and financed by the state, and the willingness and ability of states to deliver these services can differ greatly. Many other factors besides average prosperity affect childhood undernutrition, some of which (eg, female education) depend largely on public action that might be unrelated to per-head GDP.

Our study has several limitations, which we have attempted to address. The first issue relates to the quality of the measures of undernutrition used. Improvement in the underweight measure might not represent improvements in a child's nutritional status, but rather a transition to a diet that includes more sugar and animal fats.[21] This issue is less of a problem for stunting, and we have addressed the issue by reporting results for stunting in addition to underweight and wasting. The results are qualitatively similar for all three indicators, increasing our confidence in the results. The second issue is that a single reference standard for undernutrition measures might not account for genetic differences in height and weight potential across different world regions.[21] We have partly addressed this issue by including country fixed effects in the regression models, which can account for such differences between countries.

Other limitations are related to the selection of countries for inclusion in the DHS sample and the quality of the GDP data. The DHS sample includes an oversampling of economically successful countries. Some of the poorest African countries have neither the capacity nor the political stability to undertake a survey of the scale of the DHS. The quality of the per-head GDP data from the Penn World Tables is related to a country's level of economic development, with larger error margins for poorer countries than for wealthier countries.[22] The inclusion of country fixed effects in our models and the use of instrumental variable analysis greatly absorbs this bias. Furthermore, despite these issues, these are the best data that exist and all other studies have the same limitations. Nevertheless, the external validity of our results for countries not included in our sample is limited.

The final issues are related to our statistical approach. Per-head GDP could itself be affected by child undernutrition, since child undernutrition might either directly affect economic development or be a proxy for other factors that affect economic development for which we might not have accounted. A direct effect of child health on economic development could be related to the time that parents spend caring for sick or weak children; however, we believe that this direct effect, if it exists, will be quite small. Of course, child health might have very important and strong long-term effects on economic development, but such long-term effects would not affect our analysis, which focuses on the short-term to medium-term association between income and undernutrition. The contribution of children to economic growth through labour is similarly irrelevant for our analysis, because the children in our sample are too young to work.

Moreover, nutritional status of children could be a proxy for overall health conditions. We know from several studies[3,23,24] that a causal link exists between population health and economic development. We partly addressed this concern with the inclusion of country fixed effects, which absorb differences in population health. Furthermore, we reduced potential bias by adjusting for a rich set of household-level covariates. Lastly, we used instrumental variable regressions specifically to address reverse causality and unobserved heterogeneity.

In summary, the quantitatively very small to null association seen in our study suggests that the contribution of economic growth to the reduction in early childhood undernutrition in developing countries is very small, if it exists at all. This finding challenges the assumption that economic growth will automatically lead to reductions in child undernutrition. Our results therefore emphasise the need to focus on direct investments in health and nutrition[25,26] and not to rely on the so-called trickle-down approach of a growth-mediated strategy to improve nutrition in children.

Contributors

SV and SVS conceptualised the study, developed the analytical strategy, and interpreted the results. SV wrote the first draft of the report and contributed to the statistical analysis. KH did the statistical analysis and contributed to the interpretation of results and writing of the report. MAS contributed to the interpretation of the results and writing of the report. JF contributed to the statistical analysis and writing of the report. SK contributed to the conceptualisation of the study, interpretation of the results, and writing of the report. SVS contributed to the writing of the report and provided overall supervision.

Declaration of interests

We declare that we have no competing interests.

Acknowledgments

We acknowledge support from the Open Access Publication Funds of the University of Göttingen (Göttingen, Germany).

References

1 Stiglitz J, Sen A, Fitoussi JP. Mismeasuring our lives. New York: The New Press, 2010.

2 Preston SH. The changing relation between mortality and level of economic development. *Popul Stud* 1975; **29:** 231–48.

3 Pritchett L, Summers LH. Wealthier is healthier. *J Hum Resour* 1994; **31:** 841–68.

4 Smith LC, Haddad L. How potent is economic growth in reducing undernutrition? What are the pathways of impact? New cross-country evidence. *Econ Dev Cult Change* 2002; **51:** 55–76.

5 Ravallion M. Growth, inequality and poverty: looking beyond averages. *World Dev* 2001; **29:** 1803–15.

6 Drèze J, Sen AK. Hunger and public action. Oxford: Clarendon Press, 1989.

7 Headey DD. Developmental drivers of nutritional change: a cross-country analysis. *World Dev* 2013; **42:** 76–88.

8 Subramanyam MA, Kawachi I, Berkman LF, Subramanian SV. Is economic growth associated with reduction in child undernutrition in India? *PLoS Med* 2011; **8:** e1000424.

9 WHO. WHO global database on child growth and malnutrition. Geneva: World Health Organization, 2013. http://www.who.int/nutgrowthdb/en/ (accessed March 22, 2013).

10 Subramanian SV, Subramanyam MA. Economic growth & health of poor children in India. *Indian J Med Res* 2011; **133:** 685–86.

11 Harttgen K, Klasen S, Vollmer S. Economic growth and child undernutrition in sub-Saharan Africa. *Pop Dev Rev* 2013; **39:** 397–412.

12 ICF International. DHS final reports. Calverton: Demographic and Health Surveys, 2011. http://dhsprogram.com/ (accessed Oct 31, 2013).

13 Feenstra RC, Inklaar R, Timmer MP. The next generation of the Penn World Table (NBER Working Paper No 19255). Cambridge, MA: National Bureau of Economic Research, 2013.

14 WHO Multicentre Growth Reference Study Group. WHO child growth standards: length/ height-for-age, weight for-age, weight-for-length and body mass index for age: methods and development. Geneva: World Health Organization, 2006.

15 Borghi E, de Onis M, Garza C, et al. Construction of the World Health Organization child growth standards: selection of methods for attained growth curves. *Stat Med* 2006; **25:** 247–65.

16 Filmer D, Pritchett LH. Estimating wealth effects without expenditure data--or tears: an application to educational enrollments in states of India. *Demography* 2001; **38:** 115–32.

17 Acemoglu D, Johnson S, Robinson JA, Yared P. Income and democracy. *Am Econ Rev* 2008; **98:** 808–42.

18 Behrman JR, Deolalikar AB. Will developing country nutrition improve with income? A case study for rural south India. *J Polit Econ* 1983; **95:** 492–507.

19 Behrman JR, Deolalikar AB. The intrahousehold demand for nutrients in rural south India: individual estimates, fixed effects, and permanent income. *J Hum Resour* 1990; **25:** 665–96.

20 Subramanaian S, Deaton A. The demand for food and calories. *J Polit Econ* 1996; **104:** 133–62.

21 de Haen H, Klasen S, Qaim M. What do we really know? Metrics for food insecurity and undernutrition. *Food Policy* 2011; **36:** 760–69.

22 Harttgen K, Klasen S, Vollmer S. An African growth miracle? Or: what do asset indices tell us about trends in economic performance? *Rev Income Wealth* 2013; **59** (suppl S1)**:** S37–61.

23 Acemoglu D, Johnson S. Disease and development: the effect of life expectancy on economic growth. *J Polit Econ* 2007; **115:** 925–85.

24 Bloom DE, Canning D, Fink G. Disease and development revisited. *J Polit Econ* (in press).

25 Ruel MT, Alderman H, Maternal and Child Nutrition Study Group. Nutrition-sensitive interventions and programmes: how can they help to accelerate progress in improving maternal and child nutrition? *Lancet* 2013; **382:** 536–51.

26 Gillespie S, Haddad L, Mannar V, Menon P, Nisbett N, Maternal and Child Nutrition Study Group. The politics of reducing malnutrition: building commitment and accelerating progress. *Lancet* 2013; **382:** 552–69.